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(19) (CA) **APPLICATION FOR CANADIAN PATENT** (12)

(54) Safety Vent for a Sealed Prismatic Electrical Device

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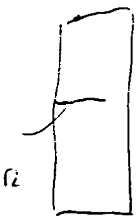
Notice: This application is as filed and may therefore contain an incomplete specification.

2165152

ABSTRACT

Safety vents comprising a weakening groove reliably rupture at lower internal pressures in sealed prismatic electrical devices when at least a portion of the groove is formed parallel to and adjacent to an edge of the container such that it traverses the perpendicular bisector of said edge. A 'U' shaped groove is particularly suitable for use in prismatic lithium ion batteries.

$\perp$ BISECTOR



SAFETY VENT FOR A SEALED PRISMATIC ELECTRICAL DEVICE

FIELD OF THE INVENTION

The invention pertains to safety vent constructions for sealed, prismatic shaped, electrical devices and, in particular, for lithium ion batteries.

BACKGROUND OF THE INVENTION

Various commercial sealed (ie. gas tight) electrical devices contain safety vents in their containers in order to relieve excessive gas pressure that can be generated under certain conditions and types of abuse. Lithium batteries comprising liquid non-aqueous electrolytes are examples of such devices. Such batteries are typically hermetically sealed in order to stop the loss of the non-aqueous electrolyte solvent via evaporation as well as to prevent air from entering which would irreversibly and detrimentally react with certain battery components. However, excessive pressure can easily be generated internally under various circumstances involving electrical, thermal, or mechanical abuse.

Recently, new long life types of rechargeable lithium batteries have become commercially available based on lithium ion electrochemistries. Lithium ion batteries have very high volumetric energy densities and consequently are preferred for applications where space is at a premium. Typical applications include cellular phones, pagers, and the like wherein it is essential that the power packs be small and thin. Hence thin prismatic (rectangular parallelepiped shaped) format batteries are preferred for these applications. To maximize volumetric energy density, the wall thickness of the battery container is minimized. However, the wall thickness must be sufficiently thick to prevent significant deformation under the internal pressures experienced during normal operation. Fortunately, the normal internal pressure of lithium ion batteries can be kept relatively low (of the order of 50 psi) thereby

allowing the use of thin wall, steel based, containers (of the order of 0.25 mm).

As with other lithium batteries, prismatic lithium ion batteries require a safety vent to release excessive amounts of internal gas that may be generated rapidly as a result of abuse. Similarly, it is desirable that the safety vent function at a low and reproducible pressure and that the vent be economical to mass produce. Numerous conventional battery designs have safety vents comprising a weakened section of container material that ruptures as a means for releasing excess gas pressure. The section can be weakened by incorporating a weakening groove, or score, somewhere in the container. The groove or score may be generated by various methods including stamping or chemical etching. Such constructions are simple (no additional components are required) and space efficient and can be reliable and economical to mass produce. Examples of such safety vent constructions for use in cylindrical batteries appear in U.S. Patent Nos. 4,722,874 and 4,789,608, amongst others.

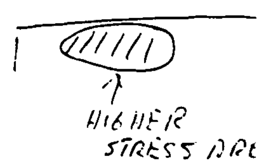
While numerous safety vent constructions with weakening grooves appear in the art, many of these constructions are intended for electrochemical systems having normal operating pressures and/or desired vent pressures that differ from those of lithium ion batteries (eg. lead acid or Ni-Cd electrochemical systems). Also, the safety vent designs that are suitable for cylindrical batteries may not be suitable in practice for prismatic batteries. Thus, many constructions in the art may be unsuitable for the requirements of prismatic lithium ion batteries.

In the art specific to prismatic batteries employing weakening groove safety vent designs, there appears to be no discussion regarding the location of the groove relative to the edge of the battery container. Two manufacturers of prismatic lithium ion batteries (AT Battery and GS Battery of Japan) currently employ a safety vent comprising a separate piece of thin film that is scored and welded as a

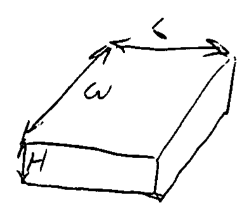
sandwich with a backup member over an aperture in the battery container. This particular type of safety vent comprises several relatively expensive components and is relatively difficult to assemble.

SUMMARY OF THE INVENTION

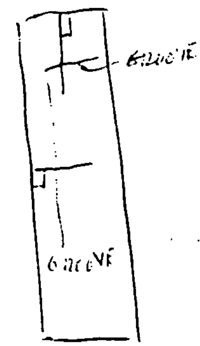
The safety vent of the invention uses, to full advantage, the mechanical stresses available when a prismatic electrical device is pressurised from within, thus leading to bursting at a lower desirable pressure. The invention is particularly suited for use in prismatic batteries. Prior art prismatic battery safety vents comprising weakening grooves do not appear to use to full advantage the mechanical stresses available when the battery is subjected to internal pressure. We have discovered that it is advantageous to locate such safety vents in areas at higher stress levels since burst pressures in such areas are generally lower and more consistent. For prismatic containers generally, the stress on the container is higher at points near the edges and far from the corners. Also, for points near the container edges, the longer the edge is, the higher the stress. Generally, the regions of absolute highest stress cannot easily be predicted once inelastic deformation occurs.



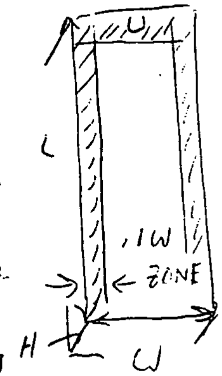
The safety vent and method of the invention have general application to sealed prismatic electrical devices conventionally comprising a metal container including an open-ended prismatic can and a rectangular cover sealed at the periphery to the open end of the can. The safety vent itself includes a weakening groove formed in any face of the container. The face is rectangular and can be described by the dimensions L and W (abbreviations for length and width). (L, W, and a third dimension H (height) therefore are the dimensions of the container.) The weakening groove is formed in the container such that the container ruptures at the groove when the internal pressure of the device



exceeds a predetermined vent pressure. We have discovered that to use the inherent mechanical stresses available during pressurization to full advantage to provide a reliable rupture at low pressure levels, the weakening groove of the safety vent should comprise at least a groove length parallel to and adjacent to a container edge of dimension L. The groove length extends a sufficient length such that it traverses the perpendicular bisector of the container edge of dimension L. In this way, the groove lies over the region of highest stress parallel to and in the vicinity of that particular edge.



The groove length is desirably located as close as is practically possible to the container edge of dimension L, preferably less than about 0.1W from said edge. Additionally, to achieve the highest stress level, the groove is desirably located parallel to the longest edge dimension of the container. Thus, L is preferably greater than W. For the same reason, L is also preferably greater than the third dimension of the container H.

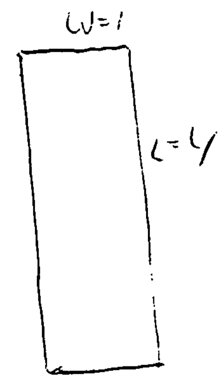


The groove length can be formed by mechanical stamping and can be located on the outside surface of the container. The container and thus the face comprising the groove length can be made of steel. To achieve the desired predetermined vent pressures for many lithium ion battery embodiments employing prismatic steel containers, the thickness of the face in the vicinity of the groove length can be about 0.025 mm. Such predetermined vent pressures can be less than about 250 psi.

A preferred location for the groove length is in the separate cover of the container. Being a separate piece, the thickness of the cover can be less than the wall thickness of the can. For instance, the thickness of the cover can be 0.25 mm when the thickness of the container is 0.50 mm. The periphery of the cover can be laser welded to the open end of the container.

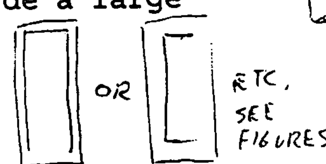
The weakening groove of the invention can additionally include a groove side leg which is perpendicular to and

continuously connected to the end of the groove length (ie. the groove side is parallel to a container edge of dimension W) thereby forming an overall groove comprising an L shape. As discussed above, the groove side may preferably lie over the region of highest local stress, a situation which is achieved if the groove side traverses the perpendicular bisector of the container edge of dimension W.



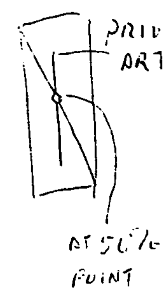
A preferred embodiment has a W/L ratio of about 1/4 and exhibits maximum deformation at distances about 0.25L from each container edge of dimension W. ?

The weakening groove of the safety vent can comprise two such groove sides perpendicular to and continuously connected to the ends of the groove length, thereby forming a U shape. Upon rupture, such a design can provide a large venting area for the rapid release of gas.



BRIEF DESCRIPTION OF THE DRAWINGS

Figures are provided herein for a preferred embodiment of the invention but these should not be construed as limiting the invention in any way.



Figures 1a and b show a cross-sectional plan view and an end view respectively of a prismatic lithium ion battery wherein the end cover includes a U-shape groove which comprises a safety vent of the invention.

Figures 2a and b show a side view and an end view respectively of the prismatic lithium ion battery of Figure 1 when subjected to internal pressure.

Figure 3 shows an end view of the prismatic lithium ion batteries of the prior art whose covers comprise conventional central linear grooved safety vents.

Figure 4 shows an end view of a prismatic lithium ion battery wherein the end cover includes an L-shape groove which comprises a safety vent of the invention.

DETAILED DESCRIPTION OF THE SPECIFIC EMBODIMENTS OF THE INVENTION

In safety vent designs comprising weakening grooves, the grooves are typically generated mechanically (eg. scored or stamped with a knife edge tool) as this is a simple and inexpensive method. A problem with this method however is that the depth of the groove is often difficult to control to the required accuracy for reliable vent rupture. Also, there is a material dependent limit to the groove depth which, if exceeded, is characterized by premature rupture. Some materials such as stainless steel, for example, are very tough, and may not rupture at a low enough pressure, even though the weakening groove may seem to be very close to rupture as a result of stamping. (For instance, the thickness of the material in the vicinity of conventional grooves can be of the order of 0.025 mm. To achieve a tight reliable range of vent pressures, groove tolerances that are small compared to this material thickness are required. Such fine tolerances can be difficult to achieve in mass production.)

Groove depth control becomes less important as the stress at the groove is increased, since rupture will occur at a lower range of internal pressure. For a given desired internal vent pressure in an electrical device, it is possible to increase or decrease the stress at the groove by modifying groove shape and/or location. Generally, groove type safety vents that operate at higher stress levels are inherently stronger, being more resistant to outside mechanical forces and internal cyclic pressure (which lead to metal fatigue).

In the art, weakening grooves are typically formed in the container parts as a separate operation (ie. after the forming of the individual container parts). The stamped container part is often post-plated with a suitable

metal (eg. nickel) to protect against environmental corrosion at the groove site. Conventionally, stamping or grooving operations are avoided near the edges of container parts because such operations can result in undesirable distortion thereof. This can be a particularly serious problem at edges wherein a seal still has to be made in constructing the container. At the unsealed edges of the container, it is generally crucial that the edges be of predictable shape and integrity in order to effect a reliable seal. Additionally, the sealing operations themselves (eg. crimping or welding) can damage and/or rupture weakening grooves that are near the edges (particularly when the edges are distorted). Nonetheless, we have found that with reasonable care, stampings of groove lengths can be made very close to unsealed edges of the container without causing serious adverse effects on the edge shape or integrity. Additionally, with reasonable care, sealing operations can be performed without damaging such groove lengths. For instance, laser weld seals have been successfully made in the Inventive Example following.

Conventional grooved safety vents, wherein the weakening groove is centrally located in a container face relatively distant from the container edges, are subject to diaphragm stresses as a result of bulging of that container face. However, the weakening groove is not stressed substantially by the bulging of other container faces adjacent the face which has the weakening groove therein.

Figure 3 shows an end view of the prismatic lithium ion batteries of the prior art whose covers comprise conventional central linear grooved safety vents.

In comparison, the safety vents of the invention take advantage of the stresses generated by the bulging of other container faces. The invention may be used for various prismatic electrical devices but is considered particularly suitable for use in small lithium ion prismatic batteries for commercial electronics applications.

While, the following description pertains specifically to such batteries, it is intended that this additionally serve to illustrate aspects of the invention in general. The invention as disclosed can be adapted accordingly to other fields by those skilled in the art.

Figure 1a shows a cross-sectional plan view of a prismatic lithium ion battery similar to that described in Canadian Patent Application Serial No. 2,131,777, by a common inventor, filed Sept. 9, 1994 comprising a unitary fill port and terminal assembly. Therein, a flat cover 1 is laser welded at its periphery to a can 2 and together serve to form a container housing an internal electrical assembly 3. The internal electrical assembly 3 typically comprises a winding of electrodes and separator foils, called a jelly square, and an organic liquid electrolyte. The electrolyte typically consists of a lithium salt dissolved in a mixture of organic solvents such as esters, ethers, and the like. Electrical connectors are provided to connect the two electrodes of the winding to the terminals. As shown, a positive electrical connector 5 connects the positive electrode to a feedthrough 6. The feedthrough 6 is isolated electrically from the can 2 by sealing gasket 11. The feedthrough 6 therefore acts as the positive terminal for the battery. Similarly, a negative connector 7 connects the negative electrode to the can 2. The can 2 and cover 1 therefore act as the negative terminal for the battery. To insulate the electrodes and connectors inside the battery, a variety of insulating pieces may be used. Thus, also depicted are lower insulator 8, upper insulator 9, and feedthrough insulator 10.

Figure 1b shows an end view of the prismatic battery of Figure 1a. The cover 1 has dimensions L and W. Formed on the outside of the cover 1 is a 'U' shaped weakening groove comprising a groove length 12 and two groove sides 13. The groove length 12 is parallel to and adjacent to a container edge of dimension L. As shown, the groove length 12 not only traverses the perpendicular bisector (shown in

dotted lines) of said container edge of dimension L, but it is symmetrically formed about said bisector. Additionally, the groove length 12 is located very closely to the container edge of dimension L (eg. less than about 0.1W therefrom). The two groove sides 13 are perpendicular to and connected to the ends of the groove length 12. As shown, the groove sides 13 traverse the perpendicular bisector of the container edges of dimension W.

It is important for purposes of the invention that the groove length be as close as possible to the container edge in order to maximize the stress level at the groove (score) site. Additionally, the groove length is ideally located parallel to the broadest edge of the container, ie. L, in order to achieve maximum stress. The groove length is thus strategically placed on the cover such that bulging of the broadest face of the can also imposes tensile stress to the groove length, ie. in addition to the diaphragm stress applied by the bulging cover 1. The groove sides 13, when ruptured along with groove 12, allow the safety vent to open further for rapid gas expulsion. Since the groove length 12 is smaller than the length of the container, the battery contents are retained when the safety vent opens.

Figures 2a and b qualitatively illustrate the effect of internal pressure on the prismatic battery of Figure 1. In Figure 2a, which shows a side view of that shown in Figure 1a, the internal pressure causes the cover 1 to convexly deform outwardly imposing a tensile stress (directions indicated by double arrows 14) along the groove length. However, as shown in the end view of Figure 2b, the can side walls 2a and 2b also deform outwardly imposing additional tensile stress (directions indicated by double arrows 15) along the groove length 12 with the greatest such stress occuring at point 12a, which coincides with the bisector. The closer the groove length 12 is to the edge of the container, the more significant is the effect of

this additional tensile stress thereon (ie. lower burst pressure for a given groove profile).

When the internal pressure is sufficiently large, the weakening groove initially ruptures at the weakest point. Thereafter, the rupture propagates along the weakening groove. Rupture along the groove length 12 and groove sides 13 allows a flap of cover material to open slightly thereby creating a sufficiently large opening for rapid gas expulsion, yet at the same time retaining the internal contents of the battery. Thus, the safety vent will not create projectiles, nor will it allow projectiles to escape from the container.

In Figures 2a and b, L is considerably more than W and so the stress at the groove sides 13 is less than that at the groove length 12. However, along the groove sides 13 themselves, the relative stress is highest at points 13a. As shown in the Illustrative Example following, the point of maximum stress along a line perpendicular to the groove side can be difficult to predict. Thus, some non-inventive empirical trials may be necessary if the groove sides 13 are to be located at positions of maximum relative stress.

The safety vent of the invention thus requires no additional parts and constitutes a design that is capable of being mass produced economically. The groove sides of the 'U' shaped groove allow a portion of the cover to hinge open to increase the vent opening.

Figure 4 shows an end view of a prismatic lithium ion battery wherein the end cover includes an L-shape groove which comprises a safety vent of the invention. As seen in Figure 4, the score is "L"-shaped with the longer groove 12 parallel to the edge of side L, while the single perpendicular groove side 13 traverses the perpendicular bisector of the container edge of dimension W.

Although the score may be applied adjacent to any broad side of the container, it is advantageous to apply the score to the cover since the material thickness thereof

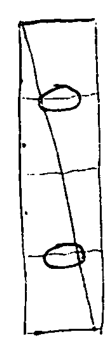
may be minimized to further increase the stress level at the groove site. Another advantage is that there is greater flexibility in the choice of the cover material (eg. a lower tensile strength material might be used) since the stamping process used to form the cover itself is less severe than that used to form the container. A lower tensile strength cover will burst at a lower pressure.

The preceding description is for one preferred embodiment of the safety vent of the invention in a lithium ion prismatic battery. However, other configurations are possible. For instance, the cover may be cup shaped with short side walls rather than flat for purposes of easy edge welding. Or, it may be desirable for certain reasons to incorporate the weakening groove in the can rather than the cover. In this case, the cover can be welded at the periphery with minimal concern with regards to damaging the weakening groove by overheating. Also, the score may be applied to the inside surface of the container rather than the outside surface. Similar concepts apply for devices other than batteries (eg. capacitors).

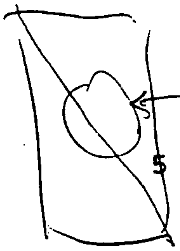
The following examples are provided to illustrate certain aspects of the invention, but should not be construed as limiting in any way.

Illustrative Example

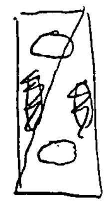
An empty container for a prismatic lithium ion battery similar to that shown in Figure 1 was prepared without a safety vent for purposes of observing the deformation that occurred when pressurized internally. Both cap and cover were made of nickel plated low carbon mild steel. The exterior container dimensions were 7.8 mm x 34 mm x 48 mm in size. The wall thickness of the can was 0.5 mm. The thickness of the cover was 0.25 mm. The cover was welded to the container using a YAG laser.



A hydraulic line was attached to a hole made in the container and the pressure was ramped therein to the



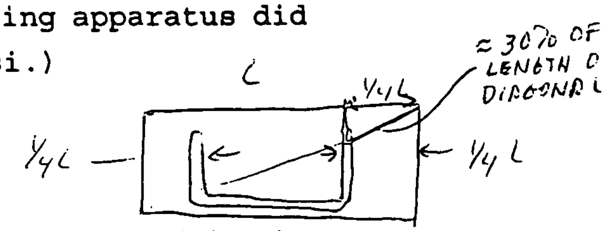
desired venting pressure range of about 300 psi. Both can and cover underwent outward inelastic deformation. The can walls bulged outwardly in a convex manner of order of 1 mm in the centre. The cover however unexpectedly became peanut shell shaped, with bulge maxima located about 1/4 of the distance in from the 7.8 mm edges.



can

Comparative Example

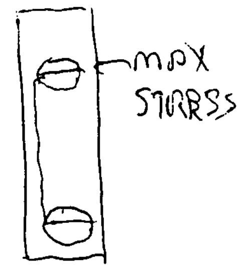
Approximately 10 covers similar to those used in the Illustrative Example had conventional central linear safety vents stamped therein according to the procedures described in the preceding. The conventional safety vents were similar to that shown in Figure 3 (comprising a central groove length 16 stamped in the cover 1) which do not fully use the stresses generated by the bulging of the can wall when pressurized. The groove stamping tool was adjusted for maximum groove depth to create the weakest possible section at the groove site (ie. approximately 10% of the original 0.25 mm material thickness remained). Attempts to make the groove weaker had resulted in premature groove rupture during the stamping process. The containers were then pressurized as before until the safety vents ruptured. Rupture occurred at pressures ranging from 300 psi to greater than 400 psi. (The testing apparatus did not permit a pressure greater than 400 psi.)



Inventive Example

Approximately 50 covers similar to those used in the Illustrative Example had 'U' shaped safety vents of the invention stamped therein according to the procedures described in the preceding. The safety vents were similar to that shown in Figure 1b. The depth of the groove was similar to that of the Comparative Examples, ie. less than 10% of the original 0.25 mm. material thickness remaining. The groove sides were located about 1/4 of the distance in

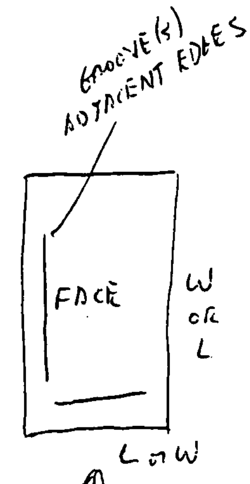
from the 7.8 mm edges (ie. the location of the bulge maxima in the Illustrative Example). The containers were then pressurized as before until the safety vents ruptured. Rupture occurred at pressures ranging from 150 psi to 250 psi. The rupture propagated along the groove sides providing a large open area for venting. Rupture therefore occurred over a narrow range of pressure and at substantially lower values than those of the Comparative Examples.



As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the spirit or scope thereof. Accordingly, the scope of the invention is to be construed in accordance with the substance defined by the following claims.

WHAT IS CLAIMED IS:

1. A safety vent for a sealed prismatic electrical device, the device having a metal container including an open-ended prismatic can with a face having dimensions L and W, and a rectangular cover sealed at the periphery to the open end of the can, the safety vent including a weakening groove formed in a face of the container such that the container ruptures at the groove when the internal pressure of the device exceeds a predetermined vent pressure, wherein the weakening groove of the safety vent comprises a groove length parallel to and adjacent to a container edge of dimension L such that the groove length traverses a perpendicular bisector of the container edge of dimension L.



2. A safety vent as claimed in claim 1 wherein the groove length is located less than about 0.1W from the container edge of dimension L.

3. A safety vent as claimed in claim 1 wherein L is greater than W. L > W

4. A safety vent as claimed in claim 1 wherein the groove length is formed by mechanical stamping.

5. A safety vent as claimed in claim 1 wherein the groove length is formed on the outside surface of the container.

6. A safety vent as claimed in claim 1 wherein the face of the container is made of steel.

7. A safety vent as claimed in claim 6 wherein the thickness of the face in the vicinity of the groove length is about 0.025 mm.

8. A safety vent as claimed in claim 6 wherein the predetermined vent pressure is less than about 250 psi.

9. A safety vent as claimed in claim 1 wherein the groove length is formed in the cover.

10. A safety vent as claimed in claim 9 wherein the thickness of the cover is less than the wall thickness of the can.

11. A safety vent as claimed in claim 9 wherein the cover is laser welded at the periphery to the open end of the container.

12. A safety vent as claimed in claim 9 wherein the thickness of the cover is 0.25 mm.

13. A safety vent as claimed in claim 1 wherein the groove length additionally comprises a groove side perpendicular to and connected to the groove length.

14. A safety vent as claimed in claim 13 wherein the groove side traverses the perpendicular bisector of a container edge of dimension W.

15. A safety vent as claimed in claim 14 wherein the ratio of W to L is about 1/4 and the groove side is formed at a distance about 0.25L from the container edge of dimension W.

16. A safety vent as claimed in claim 1 wherein the groove comprises two groove sides perpendicular to and connected to each of the ends of the groove length.

17. A safety vent as claimed in claim 1 wherein the electrical device is a battery.

18. A safety vent as claimed in claim 13 wherein the groove length and groove side form an "L" shape.

19. A safety vent as claimed in claim 16 wherein the groove length and two groove sides form a "U" shape.

20. A method for making a safety vent for a sealed prismatic electrical device, the device having a metal container including an open-ended prismatic can with a face having dimensions L and W, and a rectangular cover sealed at the periphery to the open end of the can, the safety vent including a weakening groove in a face of the container such that the container ruptures at the groove when the internal pressure of the device exceeds a predetermined vent pressure, comprising forming in the face a groove length parallel to and adjacent to a container edge of dimension L such that the groove length traverses a perpendicular bisector of the container edge of dimension L.

21. A method as claimed in claim 20 wherein the groove length is linear.

22. A method as claimed in claim 20 forming including forming in the face a groove side connected to and perpendicular to the groove length.

23. A method as claimed in claim 20 including forming in the face a groove length and two groove sides, the two groove sides being perpendicular to and connected to each of the ends of the groove length.

OYEN WIGGS GREEN & MUTALA
Patent Agents
for the Applicant

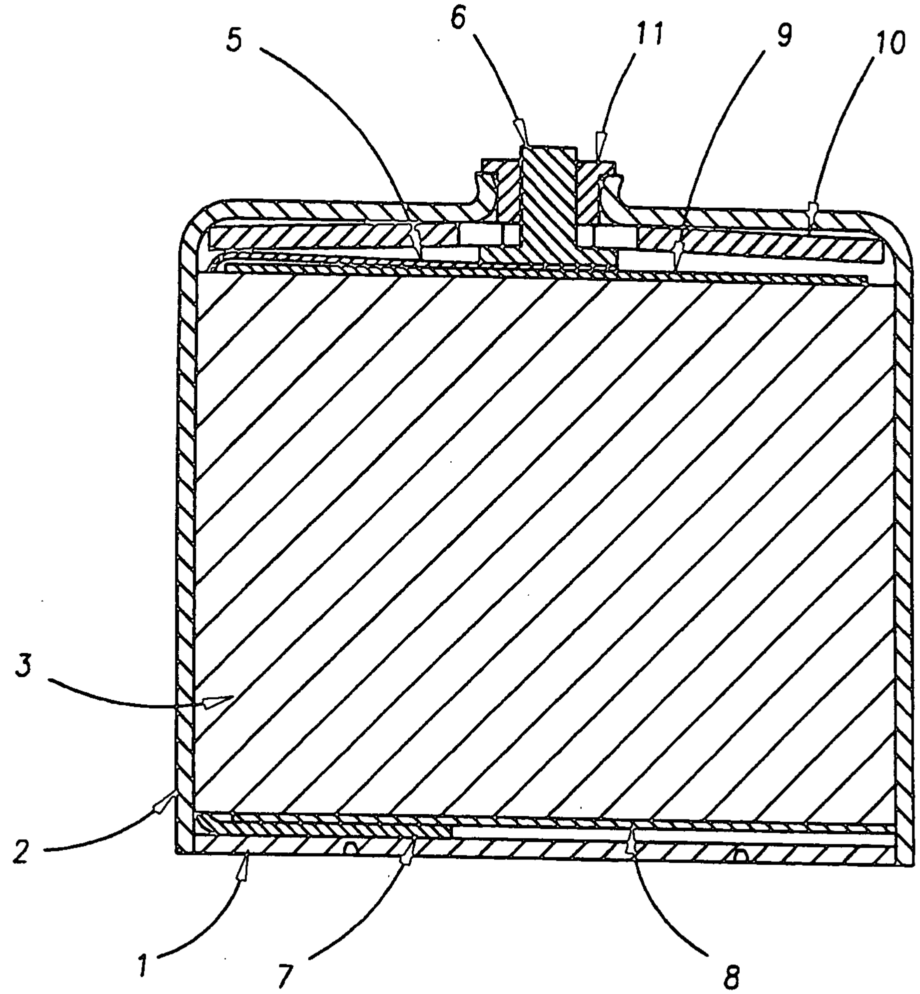


FIG. 1a

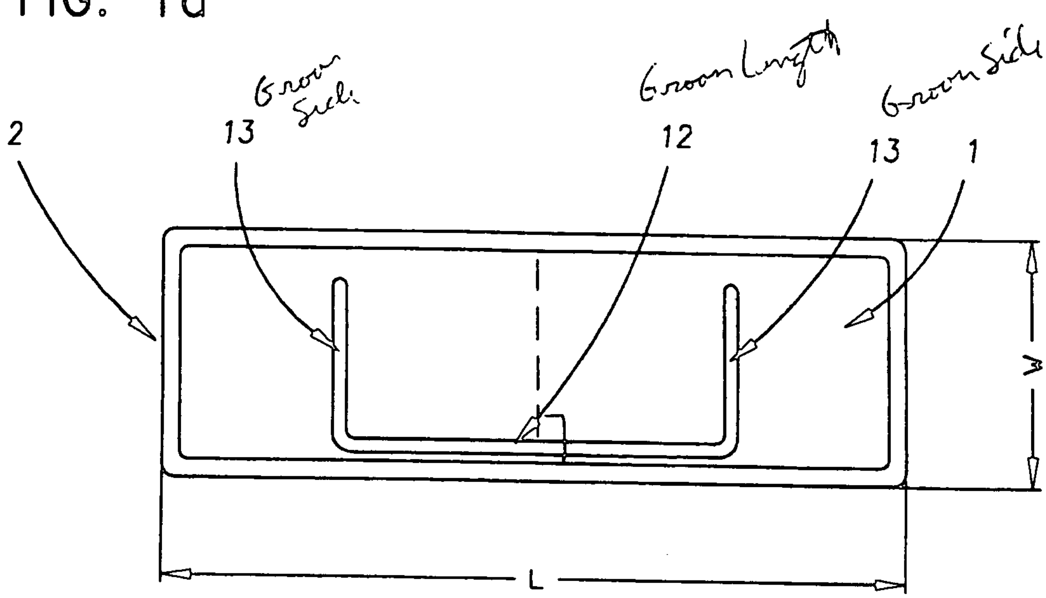


FIG. 1b

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Green & Mutala
PATENT AGENTS

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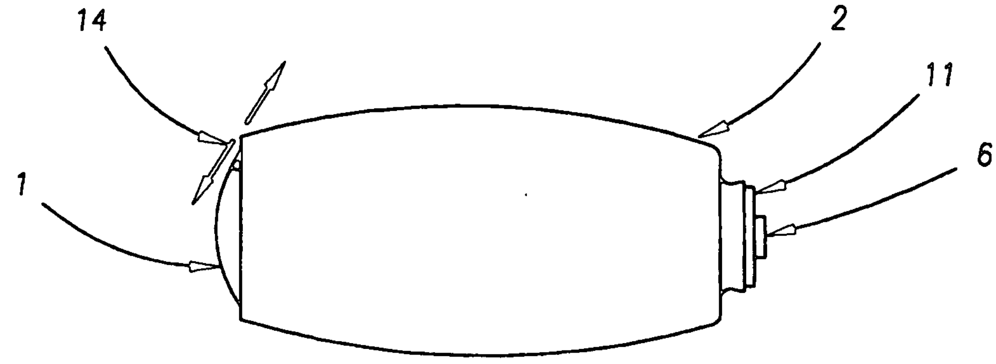

FIG. 2a

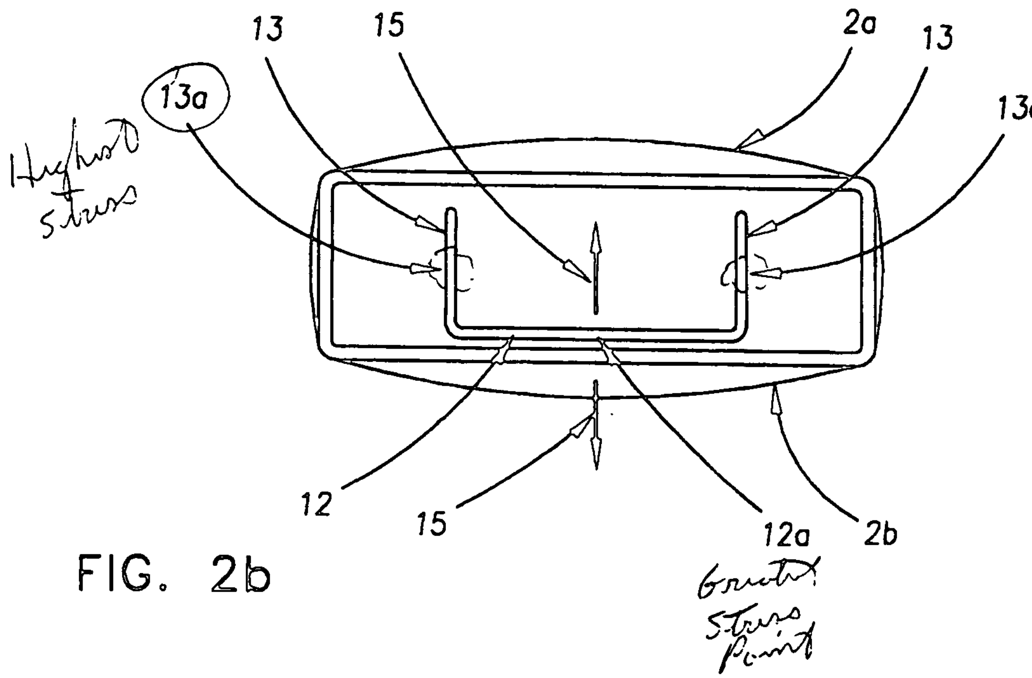

FIG. 2b

Oyen Wiggs
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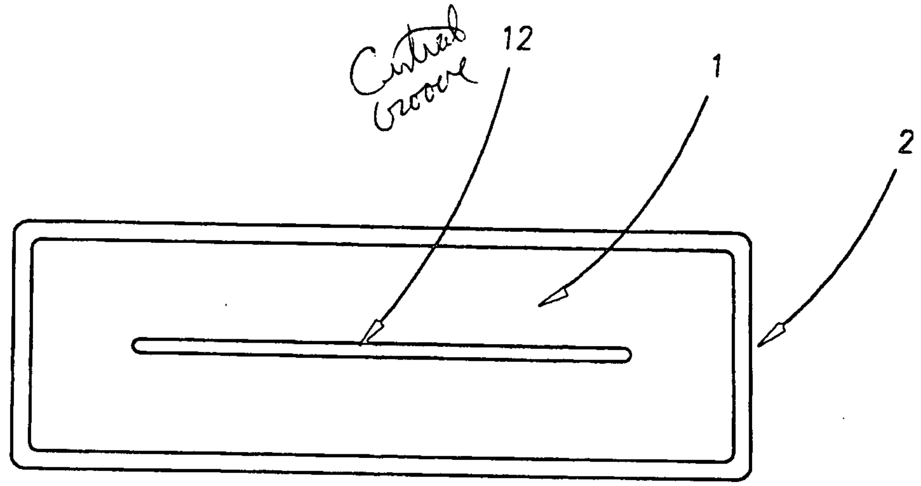

FIG. 3 PRIOR ART

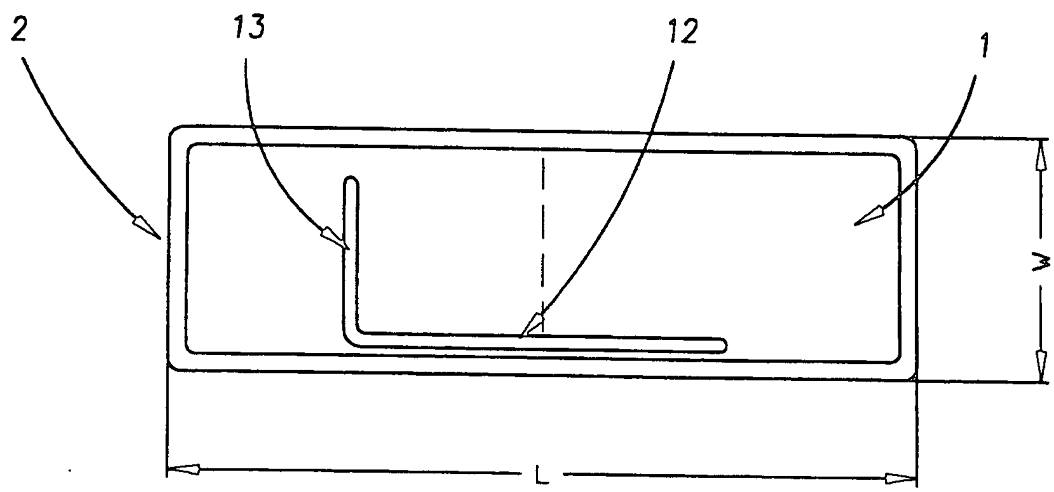

FIG. 4

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